CATERPILLAR®

Marine Engines Application and Installation Guide

- Ventilation
- Exhaust System

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CATERPILLAR®

Ventilation

General Information

Ventilation Air

Combustion Air

Sizing of Combined Combustion and Ventilation Air Ducts — Rule of Thumb

Crankcase Fumes Disposal

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General Information

There are three aspects to ventilation:

Ventilation Air

The flow of air required to carry away the radiated heat of the engine(s) and other engine room machinery.

Combustion Air

The flow of air required to burn the fuel in the engine (propulsion and auxiliaries).

Crankcase Fumes Disposal

The crankcase fumes of the engine must be either ingested by the engine or piped out of the engine room.

Ventilation Air

Engine room ventilation has two basic purposes:

- To provide an environment which permits the machinery and equipment to function dependably.
- To provide a comfortable environment for personnel.

Radiated heat from the engines and other machinery in the engine room is absorbed by engine room surfaces. Some of the heat is transferred to atmosphere or the sea through the hull. The remaining radiated heat must be carried away by the ventilating system.

A system for *discharging* ventilation air from the engine room must be included in the construction of the vessel. Do not expect the engine(s) to carry all the heated ventilation air from the engine room by way of the exhaust piping.

Routing

Correct Ventilation Air Routing is Vital

Comfortable air temperatures in the engine room are impossible without proper routing of the ventilation air.

Fresh air should enter the engine room as far from the sources of heat as practical and *as low as possible.* Since heat causes air to rise, it should be discharged from the highest point in the engine room, preferably directly over the engine. Avoid incoming ventilation air ducts which blow cool air toward hot engine components. This mixes the hottest air in the engine room with incoming cool air, raising the temperature of all the air in the engine room.

Relative Efficiency of Various Routing of Ventilation Air

The sketches on page 2 illustrate the relative efficiency of various ventilation routing:

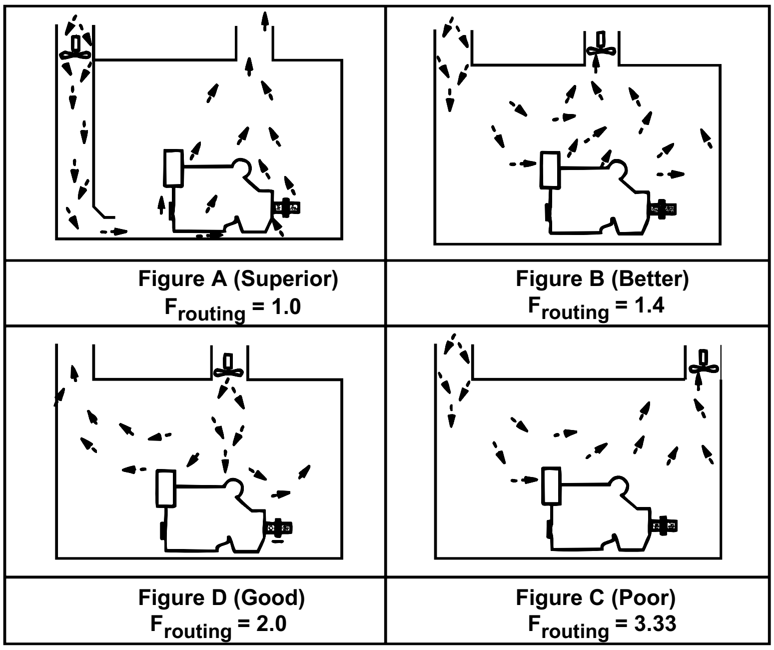


Figure 1.1

Where: $F_{routing}$ is a factor which relates the relative efficiency of various ventilation air routing.

Example:
If the routing in Figure A (upper left) is used as a base to which the others are compared:

- 1.4 times more air is required (duct cross-sectional area and fan capacity) to adequately ventilate the machinery space illustrated in Figure B (upper right).
- It takes twice as much air (duct cross-sectional area and fan capacity) to adequately ventilate the machinery space illustrated in Figure C (lower right).
- 3.3 times more air is required (duct cross-sectional area and fan capacity) to adequately ventilate the machinery space illustrated in Figure D (lower left).

Engine Room Temperature

A properly designed engine room ventilation system will maintain engine room air temperatures within 9°C (15°F) above the ambient air temperature (ambient air temperature refers to the air temperature surrounding the vessel). Maximum engine room temperature should not exceed 49°C (120°F).

Quantity Required

In general, changing the air in the engine room every one or two minutes will be adequate, if flow routing is proper.

Provisions should be made by the installer to provide incoming ventilation air of 0.1 – 0.2 m^3/min (4-8 cfm) per installed horsepower (both propulsion and auxiliary engines). This does not include combustion air for the engines. (See following remarks on engine combustion air, page 7.)

Engine exhaust ventilation air should be 110 to 120% of the incoming ventilation air. The excess exhaust ventilation air accomplishes two things:

- It compensates for the thermal expansion of incoming air.
- It creates an in draft to confine heat and odor to the engine room.

Operation in extreme cold weather may require reducing ventilation air flow to avoid uncomfortably cold working conditions in the engine room. This is easily done by providing ventilation fans with two speed motors (100% and 50 or 67% speeds).

Through-Hull Opening Design

There must be openings for air to enter the engine room and openings for air to leave the engine room.

There should be an *inlet* for cool air to enter, and a *discharge* for hot air to leave, on each side of the hull. If it is impractical to have two separate openings per side, then avoid having hot discharged air mix with cool air entering the engine room.

Design Features

Size

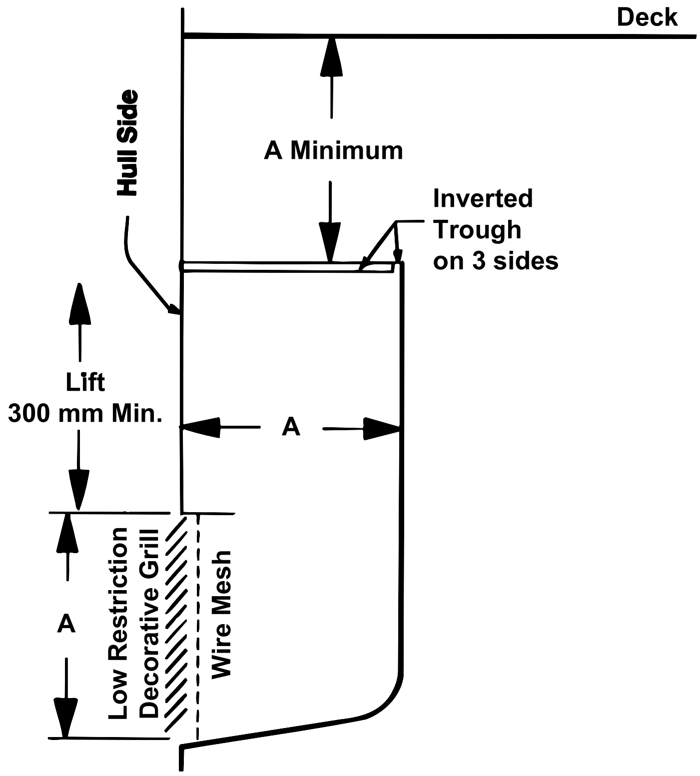
Size the openings (A) to keep the air velocity (in the openings) below 610 m/min (2,000 ft/min).

Air Entering the Engine Room

The engine room must have openings for air to enter. The air may also enter from the accommodation spaces (staterooms, galley, salon, companionways, pilot house, etc.)* or directly through the hull or deck. Engine room air inlets through accommodation spaces can be troublesome.

If air is to enter the engine room from the accommodation spaces (staterooms, galley, salon, companionways, pilot house, etc.), good design practice will include sound deadening treatments for the opening(s) which conduct air from the accommodation spaces to the engine room.

*Heating and/or air conditioning of accommodation spacecs will be made much more complicated if the engines must rely on that heated/cooled air for combustion. Engine room air inlets through accommodation spaces simplify the task of ensuring the engine room inlet air is kept clean and free from rain or spray.



Features of Through-Hull Ventilation Openings

Figure 1.2

Air Leaving the Engine Room

The through-hull or through-deck openings for discharge of heated ventilation air should be located aft of and higher than all intake openings to minimize recirculation.

- The intake air opening should be located forward of — and, if convenient — at a lower elevation, than . . .
- The ventilation air opening, discharging heated ventilation air, which should be located aft of — and at a higher elevation than the intake air opening — to minimize recirculation. Cross- and following-winds make total elimination of ventilation air recirculation impossible.

Fans

In modern installations, natural draft ventilation is too bulky for practical consideration. Adequate quantities of fresh air are best supplied by powered (fan-assisted) systems.

Location

Fans are most effective when they withdraw ventilation air from the engine room (suction fans) and discharge the hot air to the atmosphere.

Type

Ventilating air fans may be of the axial flow type (propeller fans) or the centrifugal type (squirrel cage blowers). When mounting fans in ventilating air discharge ducts (most effective location), the fan motors should be outside the direct flow of hot ventilating air for longest motor life. The design of centrifugal fans (squirrel cage blowers) is ideal.

Sizing

The *name plate* ratings of fans do not necessarily reflect their *as-installed* conditions. Just because a fan's name plate says it will move 1000 cfm of air does not mean it will move 1000 cfm through an engine room which has severely restricted inlet and/or outlet openings. Fans are often rated under conditions which do not reflect *as-installed* flow restrictions. In general, the *as-installed* conditions will be more severe than the fans name plate rating conditions.

Combustion Air

Quantity Required

A diesel engine requires approximately 0.1 m^3 of air/min/brake kW (2.5 ft^3 of air/min/bhp) produced.

Combustion Air Ducts

Design combustion air ducts to have a minimum flow restriction.

Very large amounts of air flow through the combustion air ducts.

Air Cleaners

Engines must be protected from ingesting foreign material. The engine-mounted air filter elements must never be remote-mounted, without factory approval.

If large amounts of sea spray, dust, or insects are expected, external, remote-mounted, precleaners may be installed at the inlet to a duct system to extend the life of the engine-mounted filter elements.

Air Cleaner Service Indicators

Air cleaner service indicators signal the need to change air filter elements when a restriction of 7.47 kPa (30 in.) of water — measured while the engine is producing full rated-power — develops. This allows an acceptable operating period before air filter service or replacement is required.

Duct Restriction

Total duct air flow restriction, including air cleaners, should not exceed 2.49 kPa (10 in.) of water measured while the engine is producing full rated power. It is good design practice to design combustion air ducts to give the lowest practical restriction to air flow, since this will result in longer times between filter element service or replacement.

Velocity of Air in Combustion Air Ducts

Combustion air duct velocity should not exceed 610 m/min (2,000 ft/min). Higher velocities will cause unacceptable noise levels and excessive flow restriction.

Water Traps

Traps should be included to eliminate any rain or spray from the combustion air. Rain and spray can cause very rapid plugging of the paper air filter elements on some Caterpillar Engines. This will reduce the flow of air through the engine, raising the exhaust temperature with potentially damaging effects.

Temperature

A well designed engine room ventilation system will provide engines with air whose temperature is not higher than 8.5°C (15°F) above the ambient temperature though derating of Caterpillar Marine engines is not required so long as combustion air temperatures remain below 49°C (120°F).

Rain and Spray

The combustion air should be free of liquid water, though water vapor — humidity — is acceptable.

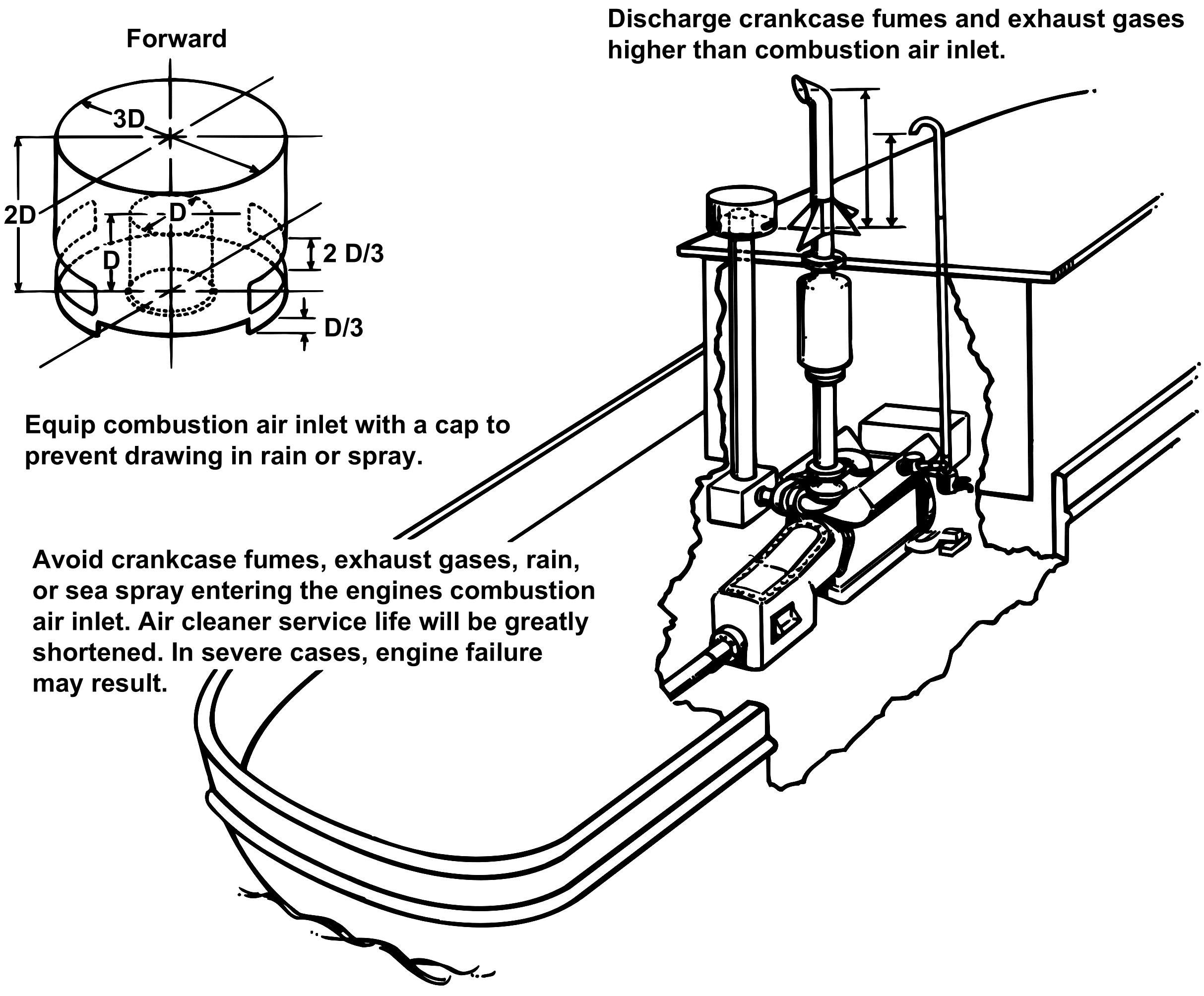


Figure 1.3

Sizing of Combined Combustion and Ventilation Air Ducts — Rule of Thumb

Air Must Be Allowed to Enter the Engine Room Freely.

A useful rule of thumb is:

- Use 4-6 sq cm of duct cross-section area per engine kW and no more than three (3) right angle bends. A larger area allows more air flow into the engine room.
- Use 0.5-0.75 sq in. of duct cross-section area per engine horsepower and no more than three (3) right angle bends. A larger area allows more air flow into the engine room.

If more right angle bends are required, increase the pipe diameter by one pipe size.

Crankcase Fumes Disposal

Normal combustion pressures of an internal combustion engine cause a certain amount of blowby past the piston rings into the crankcase. To prevent pressure buildup within the crankcase, vent tubes are provided to allow the gas to escape. 3100 and 3208 and high performance 3176, 3406, 3408, and 3412 marine engines consume their crankcase fumes, by drawing the fumes into the engine's air intake system. Larger Caterpillar marine engines must have their crankcase fumes piped away from the engine to prevent the fumes from plugging their high-efficiency paper air filter elements.

Pipe Sizing

Generally use pipe of the same size as the crankcase fumes vent on the engine. If the pipe run is longer than approximately 3 m (10 ft) or if there are more than three (3) 90° elbows, increase the pipe inside diameter by one pipe size.

Common Crankcase Vent Piping Systems

A separate vent line for each engine is required. Do not combine the piping for multiple engines.

Location of Crankcase Vent Termination

Crankcase fumes must not be discharged into air ventilating ducts or exhaust pipes. They will become coated with oily deposits.

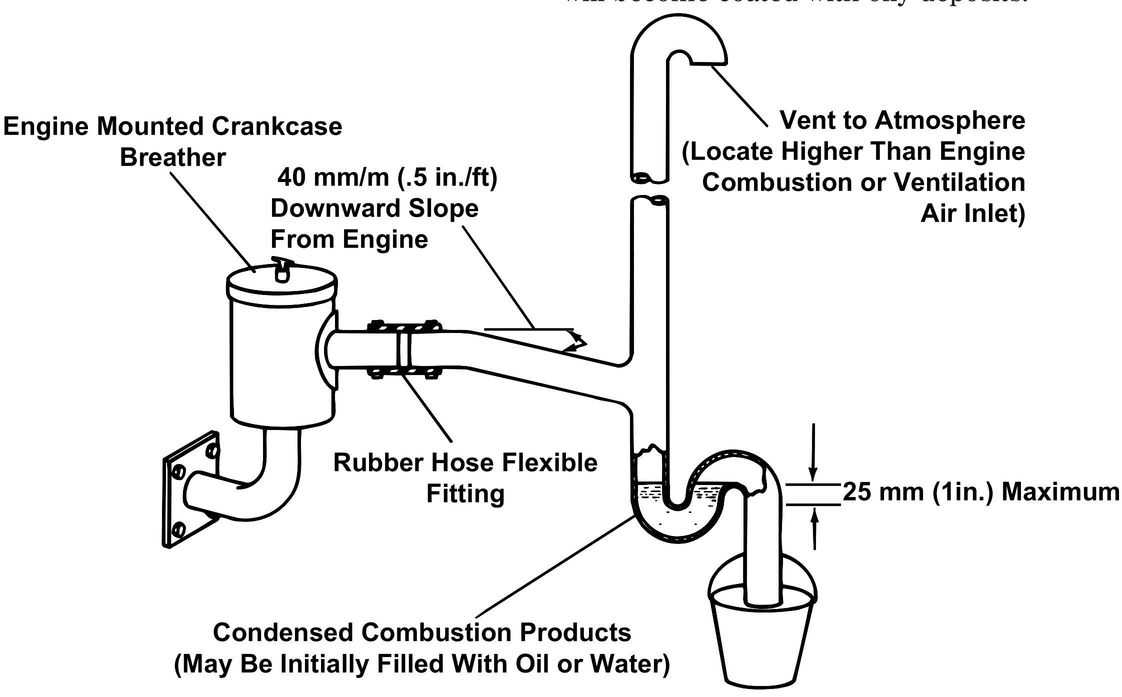


Figure 1.4

The crankcase vent pipe may be directed into the exhaust gas flow at the termination of the exhaust pipe.

Preferably, the crankcase vent pipe will vent directly to the atmosphere. The vent pipe termination should be directed to prevent rain/spray entering the engine.

Condensation/Rainwater in Crankcase Fumes Piping

Loops or low spots in a crankcase vent pipe can collect rainwater and/or condensed combustion products. These liquids may be trapped in a drip collector and drained to minimize the amount of oily discharge through the vent pipe and prevent restriction of normal discharge of fumes.

Required Slope of Crankcase Fumes Disposal Piping

Avoid horizontal runs in crankcase vent piping. Install the vent pipe with a minimum slope of 40 mm/m (.5 in./ft).

Maximum Pressure in the Engine Oil Sump

Under no circumstances should crankcase pressure vary more than 25.4 mm (1 in.) of water from ambient barometric pressure when the engine is new*. Higher crankcase pressures will cause oil leaks. A powered crankcase fumes disposal system should create no more than 25.4 mm (1 in.) of water vacuum in the crankcase.

Crankcase Volumes

The volume of an engine's crankcase is required for the sizing of crankcase pressure relief valves. See the following table.

Crankcase Volumes		
Model	Crankcase Volume	
3116	.045 m^3	(1.59 ft^3)
3126	.045 m^3	(1.59 ft^3)
3176	.14 m^3	(4.9 ft^3)
3304B	.05 m^3	(1.76 ft^3)
3306B	.063 m^3	(2.22 ft^3)
3208	.0011 m^3	(.039 ft^3)
3406B	.25 m^3	(8.8 ft^3)
3408B	.3 m^3	(10.5 ft^3)
3412	.4 m^3	(14.1 ft^3)
D399	1.28 m^3	(45.2 ft^3)
D398	.96 m^3	(33.9 ft^3)
D379	.64 m^3	(22.6 ft^3)
3508	.65 m^3	(22.9 ft^3)
3512	.98 m^3	(34.6 ft^3)
3516	1.41 m^3	(49.8 ft^3)
3606	2.3 m^3	(81.2 ft^3)
3608	3.06 m^3	(108 ft^3)
3612	3.12 m^3	(110.2 ft^3)
3616	4.08 m^3	(144 ft^3)

Many marine classification societies (MCS) expect crankcase pressure relief valves to be installed on engines with crankcase volumes more than 0.61 m^3 (21.5 ft^3) or cylinder bores over 200 mm (7.89 in.) in diameter. Caterpillar offers crankcase pressure relief valves on engines larger than the 3408.

* As the engine approaches its overhaul interval, blowby (one of the causes of crankcase pressure) will tend to increase. Careful monitoring of crankcase pressure will provide valuable guidance on the condition of an engine's valve guides and piston rings.

Special Ventilation Considerations

Refrigeration Equipment

Prevent refrigerant leakage into the engine's air intake system. Freon or ammonia will cause severe engine damage if drawn into the engine's combustion chambers. The chemicals in refrigerants become highly corrosive acids in the engine's combustion chambers.

If refrigeration equipment is installed within the same compartment as a diesel engine, the diesel engine must take its combustion air from a shipyard-supplied ductwork system which carries air to the engine from an area free of refrigerant fumes.

Exhaust Pipe Insulation Recommended

Long runs of hot, uninsulated exhaust piping will dissipate more heat into the engine room than all the machinery surfaces combined. Completely insulate all exhaust piping within the engine room area. All hot surfaces within the engine room should be insulated if high air temperatures are to be avoided.

Test With Doors and Hatches Closed

Ventilating systems must be designed to provide safe working temperatures and adequate air flow when hatches and doors are secured for bad weather conditions. Test the ventilation system with the vessel fully secured for bad weather. This condition will reflect the most severe test of the ventilation system.

Air Velocity for Personnel Comfort

Maintain air velocity of at least 1.5 m/s (5 ft/s) in working areas adjacent to sources of heat, or where air temperatures exceed 100°F (35°C). This does *not* mean that all the air in the engine room should be agitated so violently. High air velocity around engines and other heat sources is not good ventilation practice. High velocity air aimed at engines will hasten transfer of heat to the air, raising average engine room air temperature.